

ASSESSMENT OF FOREIGN COAL CONVERSION TECHNOLOGIES

Volume I

Executive Summary

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by

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STAT

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I N S T I T U T E O F G A S T E C H N O L O G Y

OVERVIEW

Through the end of this century, we expect the total world production of coal based synthetic fuels to increase to less than 1 million BOE/day from emerging technologies — about 0.7% of the world's 1980 fossil fuel production. This expectation is approximately one-third of that forecast by the International Energy Agency, High Level Group for Energy Technology Commercialization (in 1981). The primary reasons leading to the lower estimate are a series of events that were not anticipated in the post-1973 embargo era. These are:

1. World demand for energy has not increased at the dramatic rates previously expected because of conservation efforts and because of a poor economic environment in the industrial world.
2. The earlier predictions of energy shortages due to a declining natural resource base have not materialized.
3. World oil prices have not increased at the rates previously expected and are now expected to increase in real terms at only 1-2% per year.
4. The costs of energy from synthetic fuel facilities were severely underestimated in many cases due to subsequent inflation, increasing interest rates, and lack of knowledge of the technology at the time of the early post-1973 estimates. Capital constraints will hinder construction of large-scale facilities.

While all of these events are interrelated, they have had different effects on the expected development of the world synthetic fuels industry. The first two events have dampened the post-1973 urgency of the need to develop energy alternatives including synthetic fuels, to displace imported oil. This is important in that governmental agencies, particularly those of Europe and the United States, no longer feel pressed to support extensive alternative energy development. The second two events have extended the economic breakeven point for synthetic fuels relative to conventional energy such as natural gas, oil, and gasoline, by 5 to 10 years. This served to significantly decrease the willingness and capability (due to the extensive capital requirements) of private industry to proceed with large-scale synthetic fuels projects.

Together, these four events have tended to constrain the application of coal based synthetic fuels to a few end users rather than the anticipated widespread use as alternatives to natural gas, oil, or gasoline. Coal based synthetic fuels are expected to be limited to applications where there are few alternatives as has historically been the case. These include:

- South Africa due to its political commitment and need
- Japan to a limited extent because of its extreme dependence on imported energy.
- Local applications throughout the rest of the world
 - to prove selected technologies
 - where coal offers an increased feedstock capability for larger-scale petrochemical operations and where the perceived vulnerability to energy price increases is reduced (e.g., the Tennessee Eastman project in the United States)
 - where the synergism of the industrial process enhances the cost-effectiveness of the technology (e.g., Kloeckner molten iron gasification in the FRG and Sumitomo molten iron gasification in Japan: both for reducing gas in the steel industry)
 - where regulatory agencies preclude the use of natural gas as an industrial boiler fuel as is the case in the United States such that medium-Btu gas from coal provides a cost-effective industrial fuel gas.

Estimation of the economic benefits of alternative energy technologies, in particular capital intensive projects such as synthetic fuels projects requires information concerning future price increases, interest rates, availability of energy supplies, and the viability of emerging technologies. Also:

- Coal synfuels facilities will require 3 to 6 years each, for construction
- Coal gasification using advanced (2nd generation) technologies will not have been sufficiently demonstrated for large scale implementation until about 1987
- Coal-based direct liquefaction processes will not be sufficiently demonstrated for large scale implementation until about 1992.
- Coal synfuels will not be economical until the 1990 time frame at the earliest and, more likely 2000 if world oil costs sustain a 2% increase/yr.
- Alternatives to coal-synfuels are available.

Efforts to implement coal synfuels technologies by governments or corporations will only increase when the perception of the overall economic risk of construction decisions is less than the perceived overall risk of current energy policy.

Key assumptions made in the analysis, particularly with regard to evaluation of the economic competitiveness of coal based synfuels relative to the alternative sources of energy supply, include; 1) the expectation of 1-2% real price increases for oil and 2) the expectation that the estimated costs of the marginal alternatives of certain key projects such as the Soviet pipeline project are reasonably accurate. If these assumptions are incorrect the upper limit for implementation of synfuels could approach almost 3 million BOE/day by 2000. A production potential beyond that would require extensive development of the energy transportation, production, and construction infrastructure which is unlikely to be initiated unless there was a major energy shock. Even if an "all out" program were initiated, the lead time required to develop the infrastructure and technology reduces the possibility of exceeding the 3 million BOE/day upper limit. On the lower limit, we would expect development of at least 500,000 BOE/day by 2000. This represents a growth in synthetic fuel production consistent with the growth from the mid-1950's through 1980. Even in the unlikely event of significant real decreases in oil prices the lower limit will be maintained due to commitments that have already been made on projects and because of unique applications for synthetic fuels (e.g., South Africa).

EXECUTIVE SUMMARY

This executive summary presents the finding of a study intended to define the role of coal synfuels technologies in several key countries through 2000. The investigation analyzed developmental coal-synfuels processes, the existing coal-synfuels industry throughout the world, energy supply, demand, and forecasts, and potential constraints to coal-synfuels such as resources, coal port facilities, labor, product cost, and capital requirements. Coal synfuels are not expected to play a major role in displacing oil imports in the U.S.A. or its allied countries through the year 2000. The mid-1970's expectations of extensive deployment of the synfuels industry are not expected to be realized for a number of reasons — the most important being the current availability and declining real price of oil in the international market. Large-scale coal facility construction will be rare. Relatively small-scale facilities, each producing about 12,000 BOE/day or less, will be used to solve localized supply issues. World oil prices were assumed to escalate at a sustained 2%/year or 5%/year rate in this study.

The objective of this study is to examine the potential for synthetic fuels from coal throughout the world with emphasis on the major industrial countries. These countries include the United Kingdom (U.K.), the Federal Republic of Germany (F.R.G.), France, Japan, Australia, and for comparison, the United States and South Africa. The goal of this work has been to identify likely technologies to be implemented in the countries under study and to determine the net effects of coal synfuels on energy supply through the year 2000. Fuels from coal have a development history of over 100 years with the forebears of advanced technology having been developed in the 1920's. There are about 65 facilities worldwide that use coal as a feedstock for fuels and chemicals that are otherwise produced from oil or natural gas. These facilities, constructed since the late 1930's, have a combined product output of about 120,000 BOE*/day with about 100,000 BOE produced in South Africa. The 200,000 B.O.E. produced in South Africa includes the production from Sasols II and III which are presently coming on stream. Historically, only

* Barrels of Oil Equivalent.

nations deprived of imported oil for political or trade reasons, such as Germany during World War II and South Africa today, have made national commitments to coal-based synthetic fuels production. Most of the other facilities have been built to meet a local market or manufacturing need.

Figure ES1 presents worldwide historical and forecast coal-based synfuels production through the year 2000 by country as shown in Table ES1. These forecasts assume the cost of oil to increase no more than 2%/year in real terms (excluding inflation effects), with synfuels costs and constraints as outlined in this executive summary and detailed in the main body of the report. Essentially, the projects that are already committed, a number of relatively small facilities, will be implemented from 1985 to 1990. From 1990 to 1995, implementation will likely slow down as operating data are gathered on committed projects, technology development continues for several processes of technical merit, and oil prices delay construction decisions. From 1990 to 1995, we forecast the initiation of plant construction decisions based on improved operating data and economic merit. These decisions will affect the facilities on line during the 1995 to 2000 time period. The approximate doubling of coal synfuel production from 1995 to 2000 when compared to the former period is not of major significance — the actual synfuels production in BOE/day is quite low in either time frame.

Currently, there are over 40 competing coal-based synfuels technologies. (Details of these processes are presented in Appendix B.) Although there is considerable overlap in their application, commercialization of these technologies is not a simple matter of generic use. For one, thing properties of coal differ from location to location. Also, synfuels product requirements will differ by application. For example, some users of a technology might want a "clean" low-heating-value gas for chemical synthesis; while others might want liquid fuels or substitute natural gas (SNG).

One major focus of recent R&D has been to improve process efficiency so as to increase the relative output for a facility sized to handle a given coal input. Increased synfuels output would displace a correspondingly greater quantity of oil traditionally obtained from imports. Oil dependency is a key issue that has supported the interest in synfuels from coal since 1973. In Japan, for example, energy use increased by a factor of about 3.5 between 1960 and 1973, with imported oil use increasing by a factor of 8.6. In 1973, total

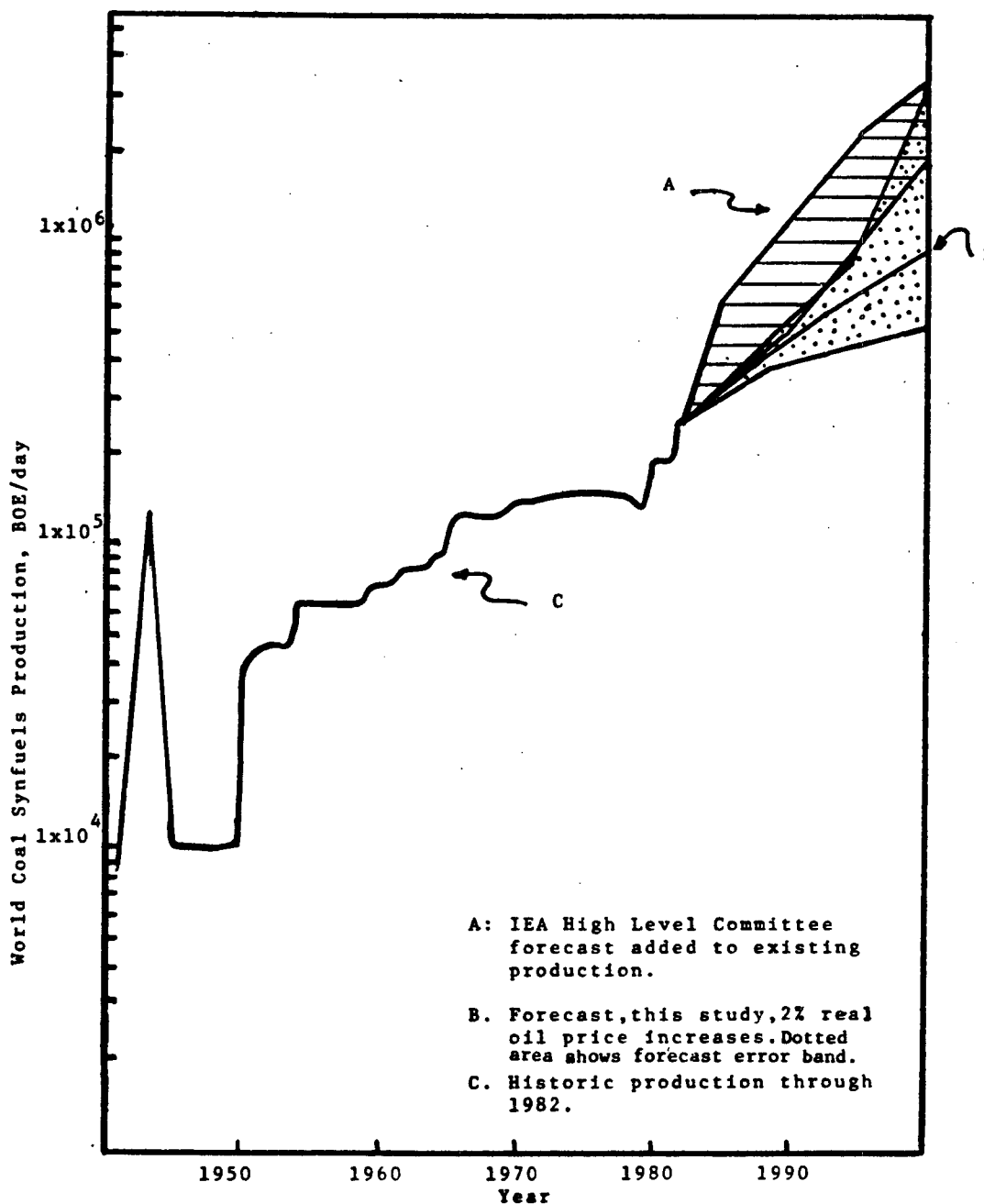


Figure ES1. WORLD SYNFUELS PRODUCTION IN BARRELS OF OIL EQUIVALENT (BOE)

Table ES1. COAL SYNFUELS PRODUCTION FORECAST^{1,5}

Country	Synfuel Type	Time Period							
		1985		1990		1995		2000	
		No. Plants	Coal Use	No. Plants	Coal Use	No. Plants	Coal Use	No. Plants	Coal Use
U.K.		0		0		0	0	0	
	Coal use (1000 metric tons/day) ¹								
	Production (BOE/day) ²	0		0		0	0	0	
France	Low and med. Btu gas	1	2	2	4	3	9	5	14
	Coal use (1000 metric tons/day) ¹		2		4		9		14
	Production (BOE/day) ²		6000		11,700		29,900		44,850
	Number of Plants	1		2		3		5	
F.R.G.	Low and med. Btu gas	5	9	6	11	6	11	8	14
	SNG	1	4	1	4	1	4	1	4
	Combined Cycle	1	4	2	9	2	9	2	9
	Direct Liquefaction	1	3	1	3	1	3	1	3
	Coal use (1000 metric tons/day) ¹		20		27		27		30
	Production (BOE/day) ²		53,900		60,000		60,000		67,500
	Number of Plants	8		10		10		12	
Japan	Low and med. Btu gas	2	4	4	7	5	9	6	11
	Combined cycle	1	4	1	4	1	4	2	9
	Coal use (1000 metric tons/day) ¹		8		11		13		20
	Production (BOE/day) ²		19,600		31,600		37,500		51,200
	Number of Plants	3		5		6		8	
Australia	Low and med. Btu gas ³	2	9	3	14	3	14	3	18
	Liquids ³	1	4	1	4	1	4	2	27
	Coal Use (1000 metric tons/day) ¹		13		18		18		45
	Production (BOE/day) ²		40,000		55,000		55,000		120,000
	Number of Plants	3		4		5		5	
U.S.A.	Low and med. Btu gas	6	2	6	11	8	16	10	23
	SNG	1	11	2	32	3	54	3	54
	Combined cycle	1	1	2	4	2	4	3	14
	Direct liquefaction	2	4	2	4	2	4	2	4
	Coal Use (1000 metric tons/day) ¹		18		51		78		95
	Production (BOE/day) ²		40,300		122,000		191,600		229,400
	Number of Plants	10		12		15		18	

Table ES1, Cont. COAL SYNFUELS PRODUCTION FORECAST^{1,5}

Country	Synfuel Type	Time Period							
		1985		1990		1995		2000	
		No. Plants	Coal Use	No. Plants	Coal Use	No. Plants	Coal Use	No. Plants	Coal Use
South Africa ⁴	Low and med Btu gas	4	80	5	100	6	108	6	108
	Direct liquefaction					1	22	1	22
	Coal Use (1000 metric tons/day) ¹		80		100		130		130
	Production (BOE/day) ²		200,000		247,000		320,000		320,000
	Number of Plants	4		5		7		7	
Other ^{5,6}	Coal Use (1000 metric tons/day) ¹	0	0	0	0	0	0	0	0
	Production (BOE/day) ²	0	0	0	0	0	0	0	0
	Total Coal Use (1000 metric tons/day) ^{1,7}		141		211		275		334
	Total Production (BOE/day) ^{2,7}		359,800		527,300		694,000		832,900
	Total Number of Plants ⁷	29		38		46		55	

Forecast based on 2%/year increases in world oil prices and constraints as defined in the text.

- ¹ Coal Input in 1000 metric tons/day rounded to the nearest ton. Facility output presented in barrels of oil equivalent/day Median values for forecast numbers are presented. Error band and forecast range; $\pm 10\%$, 1985-1990, $\pm 25\%$, 1990-1995, $\pm 50\%$, 1995-2000
- ² Process efficiency: Low and medium Btu gasification, 80%; SNG, 55%; Direct Liquefaction, 54% excluding by-products; combined cycle, 41% Coal at 11,000 Btu/lb is assumed. 1 BOE = 5.88×10^6 Btu. Then, the respective technologies noted produce 3.29, 2.96, 2.27, 2.22, and 1.68 BOE/metric ton of coal.
- ³ Japanese participation.
- ⁴ For South Africa, about 30 additional small facilities are in operation which each use 100 to 2000 metric tons/day coal. These facilities, using existing technologies have been in operation for up to 30 years. Details of these facilities are listed in Appendix C. Because a large portion of gas produced in South Africa results in indirect liquefaction, an overall conversion efficiency of 60% was assumed for gasification. Production for South Africa includes output from Sasols II and III. No new facilities expected before 1985.
- ⁵ Approximately 30 facilities of about 100 to 2000 metric ton/day coal input are in operation around the world excluding those in South Africa. These worldwide facilities use existing technology to solve localized supply problems. By 2000, about 40 of these plants are likely worldwide excluding South Africa. Though production could reach 300,000 BOE/day by 2000 from these facilities, they are not included in the totals in order to avoid confusion with emerging technologies providing additions to world energy supply or large existing facilities. Worldwide totals including small facilities are presented in Figure ES1.
- ⁶ Excludes the Soviet Union and the Peoples Republic of China. The Soviet Union is a potential purchaser of direct coal liquefaction technology under development in the F.R.G. It will not be commercial before 1992. Then, few if any facilities are likely because of the remoteness of supply and the extreme cost of a sufficient number of facilities to supply the pipeline which would also require construction. Facilities in the Peoples Republic of China are only likely with Japanese or U.S. participation. A corresponding reduction in the Australian forecast would result.
- ⁷ Excludes facilities using existing technologies discussed in footnote 5 above.

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energy demand was 337.8 Mtoe* in Japan with imported oil representing 280.2 Mtoe. In 1973, all advanced countries anticipated increased growth in GNP and energy demand through the end of the century. Also, emerging nations were thought to become increasingly dependent on oil because of its ease of use in all sectors of the economy. Traditional domestic oil supply, where available, was viewed as declining over the next several decades. Because of demand pressures and anticipated limited supply, oil prices were forecast to increase by as much as 10% per year on a sustained basis without regard to inflationary price pressures. Inflation was thought to drive oil prices still higher. With the long history of coal synfuels technology development, energy planning officials in advanced countries reasoned that the enormous coal resources of the U.S., Australia, and Canada could be used for feedstock to produce liquid and gaseous synfuels.

As a result, great reliance was put on coal-based synfuels to fill the growing gaps between domestic supply and demand in many countries while providing a cost-competitive alternative. Coal gasification was claimed to produce SNG from coal at constant costs of about \$3.25/10⁶ Btu (\$19.11/BOE) in 1976. Coal-based syncrude was expected to cost about \$25/bbl. It seemed as though coal synfuels would be cost competitive on a worldwide basis by the mid-1980's. Associated production estimates resulted. The U.S., for example was estimated by some to have nearly 200 synfuels plants producing about 8.5 million BOE/day by the year 2000 if an "all out" facility construction effort was started in 1978.

In a 1976 ERDA publication, a Stanford Research Institute (SRI) forecast for the U.S. suggested a maximum of 4 million BOE/day of methanol from coal and 4 million BOE/day of syncrude from coal by the year 2000. The study indicated the potential for 10 million BOE/day if syncrude from shale were included — all for a capital investment of about \$90 billion 1973 dollars. Forecasts of high coal-based synfuels production have been predicated on a combination of increasing oil prices and competitive costs of synfuels.

* Million metric tons of coal equivalent.

Synfuels pricing is dependent on four basic cost factors:

- Plant capital and erection cost
- Financing costs
- Coal cost
- Operating, maintenance, and labor costs.

Each of these costs has grown since 1973, and the causes and magnitude of cost growth are different for each factor. Although it has been suggested that the cost growth of synthetic fuels is driven by the price of oil, this is not true. Certainly oil price increases account for some of the cost factor increases, but at most oil price is expected to account for less than 10% of the increase in cost factors.

One major factor accounting for the growth in synfuels costs is the level of technical and engineering information available during the recent synfuels process development. In 1973, most advanced processes were at the conceptual, laboratory, or pilot plant stage. Detailed cost estimates were not possible simply because sufficient engineering information was not available to support a detailed cost estimate. Due to the stage of development and the scale-up requirements for commercial facilities, the sources of error in cost estimates were extensive. (At that time very large facilities were believed necessary to obtain scale economies and to make an impact on energy production.)

In the mid-1970's, debt financing for coal-based synfuels facilities in the U.S.A. might have been available at interest rates near 9%. Today, except for facilities with Government guarantees, the rate could likely be 15%. Similarly, expectations for rates of return on equity have increased. These effects are because of a variety of interest rate pressures in the economy rather than synfuels technology readiness. Coal costs in the mid-1970's were about \$7.00/BOE or about \$22/metric ton at the mine mouth in the U.S. Today, some plant locations are available where the coal mine could be adjacent to the synfuels plant for a continuous supply of coal at less than \$44/metric ton. This is not the case for any of the foreign countries studied except Australia. Coal is available in the U.K., but expensive and under continuing labor union pressure. For the F.R.G., France, and Japan, resources are limited or otherwise dedicated. The result is the need to import coal to operate a coal synfuels facility. Currently, the cost of imported coal is

about \$66/metric ton (about \$17.50/BOE) in the latter three countries including about \$15/metric ton or about \$4.35/BOE for shipping. Handling and transshipment costs through the country could add a few dollars per ton to this cost.

Labor costs for plant operators have increased from inflationary pressure around the world. That labor rates have approximately doubled since the mid-1970's is in itself not significant. Significant is the labor requirement for plant operation relative to importation or production of petroleum. A 50,000 BOE/day facility would employ 600 to 900 people during operation. Conventional oil production or imports would require only a few operators if they were allocated on an equivalent capacity basis.

The greatest constraint to commercialization of coal-based synfuels at this time is the low cost of imported oil relative to the total costs of synfuel production. A second major constraint is the anticipation of an uninterrupted supply from exporting countries. The U.S. Synfuels Corporation currently assumes real oil prices of about \$32/bbl to escalate in real terms (net of inflation) at about 1% per year. Most current forecasts expect oil prices to be essentially flat in real price at between \$30/bbl and \$35/bbl over the next decade. The lack of economic merit of synfuels at \$50/BOE to \$65/BOE (direct liquefaction) has resulted in large corporations cutting back on synfuels plans. As one example, International Coal Report noted that Wyoming Coal Gas, a unit of Panhandle Eastern Pipeline, was dropping plans for a 29,000 metric ton/day project to produce SNG because of "risks and uncertainties surrounding cost estimates, projected product cost, interest rates, and the world energy market outlook . . ." This particular project was to cost \$2.3 billion in 1980, but seemed closer to \$3.5 billion in 1982. The anticipated product would have a 1988 current dollar cost of about \$65/BOE. Ruhrgas (of the F.R.G.) and Pacific Gas and Electric (of the U.S.) backed out of the project last summer.

Figure ES2 presents the total cost range of coal synfuels including capital charges, operating costs, and coal feedstock. The cost range covers the broad spectrum of coal synfuels technologies. The apparent existing next best (marginal) alternatives to coal based synfuels are presented for cost comparison purposes through the year 2000. As presented in the figure, coal synfuels experienced a rapid price growth between 1975 and 1982. If these expected

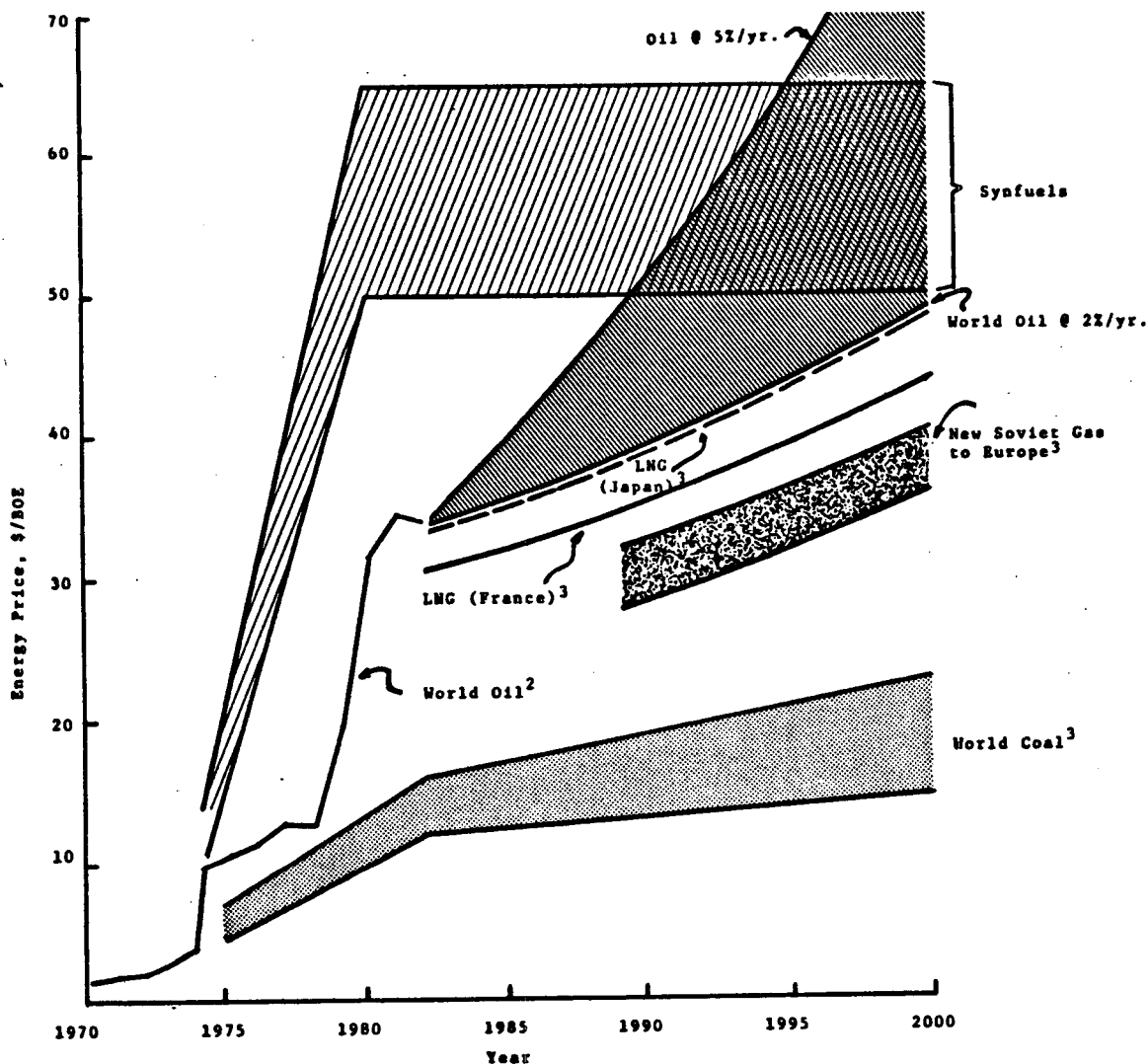


Figure ES2. COST OF COAL SYNFUELS AND COMPETITIVE ENERGY

1. Inflationary effects shown prior to 1982 as current dollar prices. After 1982, constant 1982 dollars are assumed; inflation is not accounted for after 1982.
2. Official government selling prices 1975-1981. Prior to 1975, basic long term contract prices estimated by Petroleum Intelligence Weekly.
3. Escalated at 2%/yr net of inflation to correspond to the lower case of world oil cost increases.

synfuels prices are compared to official selling prices of world oil during that time period, the apparent mistaken conclusion could be made that increased oil prices pushed coal synfuels cost and resultant prices. This subject, which is treated in Appendix A, shows that the apparent correlation does not imply a cause and effect relationship of significance. World oil prices have contributed to less than 10% of the cost growth of coal synfuels energy prices. The major contributor has been underestimation of the commercial construction costs due to lack of design detail in analysis emerging in the mid-1970's. With the construction of the 125 million SCF/day (20,000 BOE/day) SNG facility at Beulah, North Dakota, Sasol II and III, and firm plans for demonstration plants around the world, the synfuels prices indicated in the figure as \$50/BOE to \$65/BOE are likely to be indicative of actual costs. That is; coal-based synfuels entered the cost growth phase due to R&D requirements and lack of system understanding. Future cost growth and price growth are likely to be linked to inflation, which is not accounted for in Figure ES2 after 1982.

The figure presents two cases for world oil price increases: 2% per year on a sustained basis and 5% per year on a sustained basis. Again, inflation is not accounted for in these projections. If world oil prices increased in real terms at 1% per year through the year 2000, the world oil price would then be \$40/Bbl in 1982 dollars. At a sustained 10% increase/year, the world oil price would be about \$190/Bbl in real (1982) terms. As can be seen from the figure, at a 2% increase in world oil prices coal synfuels would become competitive shortly after the year 2000. If world oil prices increase at 5% per year, synfuels would become economically competitive between 1990 and 1995. At an anticipated increase in world oil prices of 10% per year on a sustained basis, coal synfuels would be economically competitive by 1985. Any coal synfuels facilities have a 3 to 7 year lead time from construction initiation to synfuels production. Then, the construction decision would often be made in advance of the breakeven year. That coal synfuels facilities are currently being canceled indicates in part that industry does not anticipate sustained oil price increases of 5% to 10% per year.

Oil, of course is not the only alternative to coal synfuels. The French import liquefied natural gas (LNG) from Algeria at a current cost of about \$4.75/10⁶ Btu (\$27.93/BOE). The French government pays 13% more than this

current Gaz de France price. Japan imports LNG from Alaska, Indonesia, and Saudi Arabia. The current Alaska price is \$5.77/106 Btu (\$33.92/BOE). These prices are tied to world oil prices, so at a 2% sustained growth per year existing LNG imports are less expensive than coal synfuels. LNG is supply limited, however, so it will not categorically substitute for coal-based synfuels.

A second alternative for Europe indicated in Figure ES2 is gas from the Soviet Union. The gas price has been negotiated at about \$28/BOE excluding inflation through the pipeline construction period. Exports to Europe of up to 700 thousand BOE/day are anticipated. The combined technical abilities of the Europeans, the potential use of U.S. or Soviet compressor technology by the Soviets, or Europeans, and a supply of about 400,000 workers from Viet Nam and partial gratitude for Soviet support to that country will help assure the pipeline's eventual success if not timeliness.

A final item indicated in Figure ES2 is coal price. The 1982 prices have been escalated at 2% per year to follow the lower case for oil price escalation. Because of relatively low-cost oil, the market for coal has weakened. Except in times of constrained oil supply, coal prices must be substantially less than oil prices because of coal's greater cost of handling, storage, and utilization as boiler fuel or as a feedstock for synfuels. Cost constraints are the current apparent barrier to coal-based synfuels. Once this constraint is removed by increasing world oil prices relative to synfuel costs, a number of additional constraints must be considered. For example, several of the advanced technologies are not ready for commercial installation; there is a need for continued development, which has been curtailed over the past year. These are direct liquefaction technologies and gasification technologies directed at SNG production. Only through continued development and demonstration plant construction will several of the individual technologies in this group be commercially viable by about 1987 (for gasification) and 1988 to 1990 for direct liquefaction. A slowdown in the expensive demonstration phase of these technologies will likely preclude construction of all but a few of these advanced facilities before the year 2000 in the capacity range of 50,000 BOE/day. Alternatively, tried and proven technologies such as Lurgi and Koppers-Totzek would capture a larger market share.

ES-14

Another major constraint to commercialization of coal-based synfuels is the capability of the existing infrastructure. In France, the F.R.G., and Japan, coal-handling facilities at the ports would require expansion to handle imports. In the U.S., Canada, and Australia (as well as the Peoples Republic of China) mines would have to be opened, inland transportation to the port cities would require expansion, and the handling facilities and ship draft capacity at the ports would have to be increased. For the U.S., expanded coal exports might require U.S. flag ships, adding over \$30/ton to shipping costs. These expansion efforts are underway worldwide but not sufficiently to accommodate a wide-scale, coal-based synfuels energy industry in any country investigated. (See main body of this report.) The only relief for long waits for loading at coal ports recently has been a softening of coal demand. France and the F.R.G. will rely on the \$110 million Dutch Maasvalkte coal terminal (MCT), which will have an initial capacity of 6.5 million tonnes a year in 1985. One partner in the project, British Petroleum (BP) has dropped out because of the stated belief that European coal consumption has been overestimated for the future. Construction will continue, but expansion of this facility or any similar facility worldwide would place strains on transshipment or inland transportation. At the MCT site, a coal slurry pilot project is under consideration.

Serious efforts to build a coal synfuels industry are dependent on simultaneous construction projects for transportation, handling, and the coal conversion facility. If facilities on a 50,000 BOE/day scale are to be constructed, special labor issues develop that act as time constraints and cost increasing constraints. Exxon R&E has recently indicated that the construction process in similar large-scale chemical plant projects is hampered by continuous hiring requirements caused by labor turnover rates higher than for small construction projects. The result is a shortage of skilled labor for facilities under construction distant from large urban centers of labor supply. As the labor force becomes less skilled from turnover and scarcity of supply, construction delays tend to develop. Exxon indicated, for example, that a facility could take about twice as many manhours to construct in areas of the U.K. than on the west coast of the U.S.A.

Once coal synfuels technologies become cost competitive with alternatives, and assuming national dedication exists to eliminate labor, environmental, and coal handling constraints, capital availability will become a dominant constraint. Coal synfuels facilities are highly capital intensive.

No country analyzed seems capable of forming the capital required to support a coal-synfuels industry or capable of displacing significant oil imports, through traditional financial markets. Industries such as the petroleum, coal, chemical, natural gas utility, and steel makers would not be able to support coal synfuels as well as traditional investment requirements.

An alternative forecast, not developed in this study, is presented as Figure ES3. These data are based on an aggressive implementation approach with political support in each country. But each country under study has demonstrated differing approaches to coal synfuels. Information currently available indicates the large-scale coal synfuels implementation of Figure ES3 will not take place. Country specific information is summarized as follows:

F.R.G.

The primary interest in the F.R.G. synfuels demonstration program is not in domestic installation, but as a showplace for technology for export sales. The ongoing demonstration program represents a low cost for international acclaim in the technology area and the appearance of concern for synfuels commercialization.

Sufficient coal resources are not available for a synthetic fuels industry. Imported coal would likely cost about \$66/metric ton of coal P.O.E. or about \$3.00/106 Btu. Including synfuels plant efficiency, capital charges, and other operating costs, synfuels from imported coal would be close to \$10/106 Btu generally speaking. Coal resources not dedicated in the F.R.G. will be more costly to produce than imported coal. Currently, coal produced in the F.R.G. costs about 50% more than world market prices of U.S., Australian, and South African coal. As a result, a subsidy of \$27/metric ton for the first 5 years of coal synfuels plant operation has been provided by the F.R.G. if West German coal is used.

Sales or trade of the liquefaction technologies to an Eastern European country, possibly the Soviet Union, has potential. Coal deposits could then be utilized and liquids production increased in those countries providing that a pipeline is built from the coal areas to the utilization areas.

The policy of utilities in the F.R.G., such as Ruhrgas, is the lowest cost option. This is to be provided in part by Soviet gas, but later from Norwegian gas and perhaps LNG.

Table ES2 indicates that the F.R.G., like France and Japan, intends to develop a significant nuclear industry by the year 2000. Also, the F.R.G.

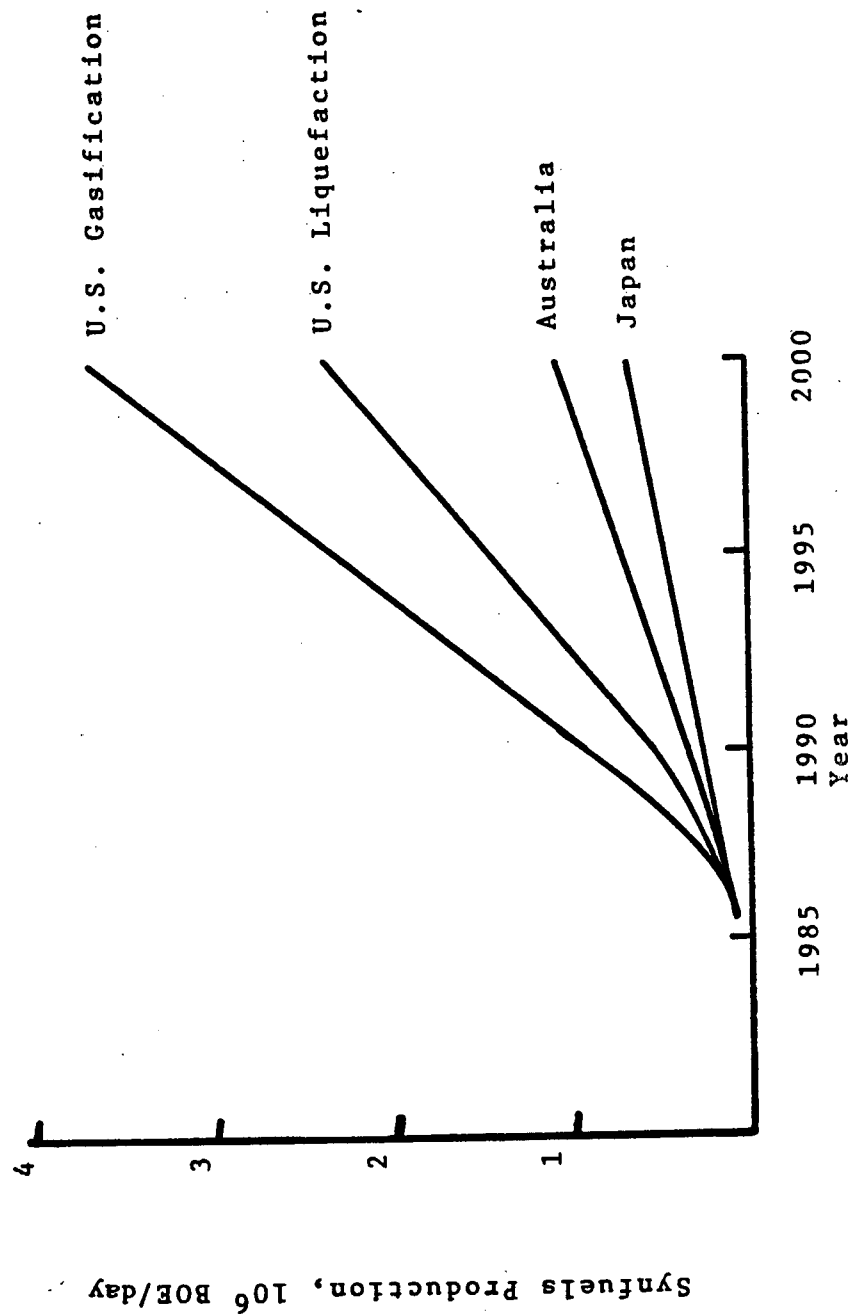


Figure ES3. COAL SYNFUELS PRODUCTION FORECAST, HAGLER BAILLY
(Hagler, Bailly & Co., Ref. World Oil 6/81)

anticipates increased gas imports from the Soviet Union. In spite of U.S. efforts to block the Yamal pipeline project, it will likely only be slowed down a few years. The new gas, to be purchased at about \$28/BOE, is regarded as an energy bargain which could substitute for gas and oil from alternative sources, including synfuels. Lignite production will remain flat, and hard coal production is forecast to nearly double with coal use for synfuels. In addition to the demonstration plants currently under construction or consideration, three or four Kloeckner process installations at steel mills and perhaps two to three combined cycle facilities for electric power generation could be built by the year 2000. If the 3-4 Kloeckner processes were three combined cycle facilities, and one or two synthesis gas plants for SNG or chemicals were built, a total energy contribution of less than 0.5 quad would result.

Table ES2. WEST GERMANY: FUTURE ENERGY REQUIREMENTS^a
(million metric tons hard coal equivalent)

	<u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
Mineral oil	187.0	166	158	142
Natural gas	65.2	73	75	73.5
Hard coal	77.0	93	114	132
Lignite	38.5	40	40	39
Nuclear power	14.0	24	40	73.5
Other ^b	<u>9.3</u>	<u>9</u>	<u>13</u>	<u>30</u>
Total	<u>391.0</u>	<u>405</u>	<u>440</u>	<u>490</u>
% change per year	--	+0.7	+1.7	+1.1

^a Source: Esso A.G.

^b Including hydro-electricity (around 7-8 million metric tons of coal equivalent) in most years and solar energy (18 million metric tons of coal equivalent mostly through heat pumps) in 2000.

France

The majority of French coal imports are for Electricite de France (EdF). While coal imports had been increasing to about 27 million metric tons in

1979, nuclear power plant construction was underway. EdF claims the 15 nuclear units on line since 1980 produce power at a cost 30% less than coal plants. Coal imports are expected to generally fall in France until about 1990, when the government claims 16 million metric tons/year will be used in the industrial sector. Currently, the only significant users are the cement industry and the steel industry: each consumes about 1.5 million metric tons/yr. It seems doubtful that industry would significantly change its use patterns, especially with low cost electric power available.

Coal gasification has not been a major concern in France. Blending medium-Btu gas with vaporized LNG has been a possibility at Le Havre to extend LNG supply, but the economics are not currently viable. The gas from coal would cost more than the LNG per unit energy. Also, France is scheduled to receive additional Soviet gas once the ongoing pipeline project is finalized and constructed. The following coal synfuels facilities had been considered in France:

Le Havre — 0.35 million metric tons/yr for medium Btu gas

Lorraine — 1.5 million metric tons/yr coal-to-methane

Nord Pas de Calais — 0.5 million metric tons/yr for chemical feedstock.

The decision on the former is due in early 1983. If positive, one plant could be in operation by 1986. The latter plants have no definite decision dates. If we assume their construction by 1990 and additional facilities by 2000, France could have five to eight small gasification plants in place by that year. The resultant energy contribution would be about 45,000 BOE/day based on five plants at 2700 metric tons/day each.

Table ES3. SOURCES OF FRENCH GAS SUPPLY IN 1990:

Domestic	8%
Netherlands	8%
Algeria	23%
USSR	32%
West Africa	16%
Norway	13%

Japan

The Japanese have had a strong history of coal use, especially for electric power generation. Consumption peaked in 1965 at just over 20 million metric tons of coal. Power generation coal use declined sharply to about 7.2 million metric tons by 1975 and up to 8.36 million metric tons in 1979. Japan has demonstrated its ability to use coal, whereas in the U.S. coal had been phased out earlier. Future domestic coal production is claimed to be about 20 million metric tons/year. Imports will increase from about 58 million metric tons/yr in 1977 to 178 million metric tons in 1995 according to MITI. Separately, International Coal Report has indicated that Japan would have difficulty holding domestic production near the 20 million metric tons/year mark. Though past coal use for electric power generation is notable, it is minor compared with forecast coal use.

According to MITI, oil imports are forecast to level off after 1985. Nuclear power is to contribute 14.3% of demand by 1995 — up from 2% in 1977. All exotic fuels and synfuels are to contribute up to 7.6% of supply by 1995, or about 2 quads of energy. Figure ES3 indicates about 1 quad of energy from synfuels for Japan by 1995. If only 1 quad was under production, about 500,000 bbl/day production would be required. This is the equivalent of 5 very large facilities or ten 500,000 bbl/day units. A 1-quad potential is unlikely for Japan by 1995. For one reason, the direct liquefaction technologies are likely to be ready for large-scale use by 1992 at the earliest. Recent SRC II cutbacks will set back the Japanese in technology timing. Another setback is in coal pricing. It is doubtful the Japanese will have more than three major liquefaction facilities in operation by the year 2000; these would likely be built in Australia or China.

U.K.

The U.K. is developing synfuels technologies without the apparent gaseous or liquid fuel needs in the home market. The reasons are threefold:

- The research facilities are essentially in place and ongoing.
- Coal is a major political and employment issue in the U.K.
- The hope of export sales of the technology

No private company without full government support is likely to construct synfuels facilities in the U.K. The country will try to sell technologies and possibly coal to others, but the market is vague. Only one or two demonstration facilities will result in the U.K., with no commercial implementation. Currently, the British have canceled plans for direct liquefaction development. The Slagging Lurgi gasification technology is being offered commercially with no implementation planned.

Australia

Exxon forecast synfuels production of about 4 million bbl/day for Australia in 2000. This represents 40 to 80 coal or shale oil plants. The forecast, based in 1980, was previous to shale operations winding down in the U.S. due to high plant cost. The energy produced, some 8.6 quads/year, would represent 28% of Australian demand by the year 2000 according to Exxon (World Energy Outlook, 1980). This production is not likely to exist without export demand from Japan. Because major facilities are not going through as planned, and world oil prices are relatively low, about four facilities are forecast by 2000.

USA

The USA has more potential for developing synfuels from coal than any other country for the following reasons:

- Coal availability
- Site/water availability
- Technology availability (U.S. or foreign)
- High oil imports.

The issue is the cost of synfuels and national policy. Private investors will not build plants unless they are either clearly competitive with alternatives or have loan and price guarantees as well as a captive market to ensure success. Current world oil prices (Figure ES2) are insufficient for coal-synfuels development. Many energy economists forecast real oil prices as increasing no more than 2% to 5%/yr in real terms between 1980 and 2000. Significant numbers of plants will not be built by the year 2000 in the U.S. because of the lack of synfuels product price competitiveness. It is likely that the SNG facility at Beulah, North Dakota, will be one of only two or

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three built in the U.S. by 2000 partly because of lower cost conventional gas from exploration and development.

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